



NASA STTR 2006 Phase I Solicitation

T6 Kennedy Space Center

NASA's launch headquarters, John F. Kennedy Space Center (KSC), is America's gateway to the universe and its busiest launch and landing facility. KSC at the Cape Canaveral Spaceport is NASA's Spaceport Technology Center, a world-class resource for the space transportation industry. KSC is helping to set the standard for future spaceports everywhere. Designers of new space transportation systems and architectures are integrating KSC-developed spaceport and range technologies into those designs to lower not only the costs of building the flight and ground systems but also of maintaining and operating them. Visionary approaches and strategies being developed today at KSC are laying the groundwork for the Cape Canaveral Spaceport and other spaceports and ranges of the future. We want to continue to offer safe and cost-effective space access for our nation and international partners' needs.

Subtopics

T6.01 Predictive Modeling Techniques for the Mechanical Behaviors of Powders, Granular Materials, and Soils

Lead Center: KSC

Center: KSC

Developing software models to predict the mechanical behavior of granular materials and powders is an area of on-going and active research and development. NASA has a need for advances in software modeling techniques to support a number of on-going initiatives. One such area is the prediction of stress/strain shearing and compaction response of powder insulation materials located inside the annular space of very large cryogenic dewars (e.g., 80 feet in diameter with a 3 - 4 foot radius in the annular space). This is an area of high interest to KSC due to the use of large cryogenic tanks at the launch pads and the problems associated with the insulation in them. Another area of interest is the mechanical behavior of lunar soil during drilling and digging, during construction and compaction (of berms), or during beneficiation and chemical processing of the soil (e.g., to remove water ice). This area is of interest to KSC due to the need for launch-site facilities to enable the assembly, flight qualification, and final checkout of spacecraft and payloads including the re-testing of last-minute modifications. Modeling the behavior of lunar soil in such facilities and comparing to the expected behavior in the lunar environment is a critical ability for developing launch-site facilities and procedures.

In both areas of interest, it is impossible to perform full-scale testing of the material in the relevant environment, and therefore extrapolation is necessary to compare small-scale or terrestrial experiments against what is expected in the full-scale or lunar environment. Extrapolation from one scale (or one environment) to another is very difficult and currently has a low probability of producing high-fidelity predictions. Unfortunately, without such extrapolation it is impossible to use an affordable small-scale (or terrestrial) test as a means to validate the design of hardware or to validate the expected behavior of the powder or soil in the full-scale (or lunar) case.

The best, presently-known method to do an extrapolation from one scale (or environment) to another is to produce a computer model to realistically simulate the physics of the granular material. The simulation can then be parameterized to make predictions in either scale or in either environment. The simulation can be benchmarked using the accessible scale (or environment), and then the parameterization can be adjusted to the inaccessible scale (or environment) to make the predictive extrapolation. Additional confidence in the extrapolation can be obtained by studying the model's sensitivity upon its various parameters within some experimentally-accessible range. Furthermore, the model can be used long-term as an engineering tool, iteratively refining it as new data become available from the full-scale application (or from the lunar environment). Thus, the model becomes a method to organize and compare new data as they become available across multiple scales and environments.

Innovations are sought in the area of multi-scale granular material modeling with true extrapolatory, predictive power across scales and environments. These innovations could be in the form of software techniques that integrate Discrete Element Models with Finite Element Models (or other software innovations), benchmarking techniques that integrate experimental methods with modeling methods in new ways, innovative analysis techniques, or any combination of the above. Other innovations will also be considered. The key point to the innovation is that it must extend the state-of-the-art in predicting granular/powder mechanical behavior. Innovations are particularly desired in the ability to model and predict powder shearing and compaction and to model lunar soil geotechnics.

T6.02 Predictive Numerical Simulation of Rocket Exhaust Interactions with Lunar Soil

Lead Center: KSC

Center: KSC

One of the major challenges routinely faced at the Kennedy Space Center's launch and landing sites is to prevent hardware damage from the blasts associated with launching spacecraft. This includes the prediction of the aerodynamics and vibro-acoustics of rocket plumes in the launch environment, the reduction of high velocity ejection of materials by the rocket plume, and protection of the surrounding hardware from these effects. This will be a greater challenge at extraterrestrial spaceports. When a spacecraft lands on the Moon, surrounding hardware may be damaged and contaminated by the high velocity spray of eroded soil particles, and the landing spacecraft may be affected by an upward spray along the reflection planes between multiple engines. On lunar spaceports, the blast protection infrastructure must be constructed (in part) using in-situ materials, such as a berm made with lunar soil. There are a number of mission scenarios that will be different than the Apollo experience and that cause the erosion problem to be more significant. Thus, this needs to be assessed in hardware and architecture design.

The lunar soil erosion theory developed during the 1940's and 50's did not include some of the relevant physics and as such it does not allow us to quantitatively predict the blast effects (with sufficient confidence) for missions that include multiple spacecraft landing in close vicinity to one another on the Moon. Without these predictions, it is currently not possible to develop adequate blast mitigation and protection technologies. To obtain better predictions, the Kennedy Space Center desires the development of a software tool that numerically predicts the plume interactions with the soil for rockets landing or launching on the Moon, including the erosion rates and trajectories of ejected particulate matter.

Innovations are sought, resulting in the development of a software package to improve the prediction of lunar blast dynamics. The difficulties in developing a flow code to predict these effects include the unique lunar environment, the difficulty in solving flow physics from first principles around discrete particle assemblages, the large spatial scale of the flow features compared to the vast number of lunar soil particles within that region, and the need to parameterize the erosion of soil to produce realistic predictions (although realistic benchmarking experiments of lunar erosion are difficult to perform terrestrially). In recent years, researchers have been making significant progress in understanding the interactions of particle assemblages with fluids. Emphasis shall therefore be placed on the research effort extending this progress toward correctly describing the physics of the gas/soil interactions.